Treatment of Dairy Waste by Aeration
I. Methods of Study*

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The Dairy Waste and Disposal Committee of the Dairy Industry Committee recently requested the Bureau of Agricultural and Industrial Chemistry to study certain phases of the disposal of dairy waste. The problem was assigned to the Eastern Regional Research Laboratory, which is investigating utilization of milk by-products.

Although the problem of dairy-waste disposal was apparently solved some years ago, there has been a resurgence of its importance because of increasing pressure from farmers, sportsmen, and others interested in clean streams and enforcement of stream-pollution laws. Recent contributions by such investigators as Bloodgood *(2)*,‡ Eldridge *(3)*, and Trebler and Harding *(16)* emphasize the high oxygen demand of such wastes and the need for further study of this problem. That dairy waste is an important cause of stream pollution is indicated in the Report of the Ohio River Committee, which devotes a section to this subject *(12)*. In the more recent report of the Kansas River Basin Water Pollution Investigation *(11)*, it is noted that of the 277 industrial establishments surveyed, 121 were concerned with milk. Agar believe that as much as one-third of the stream pollution in New York is due to dairy wastes *(1)*. These figures reflect the scattering of the dairy industry, the small size of each plant, and the inability of the various plants to treat the wastes satisfactorily.

The waste from a plant practicing good housekeeping may contain one percent milk. As the composition of such waste (which is low

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‡ Italicized figures in parentheses refer to entries in the Bibliography, page 135.

in fat) approximates that of a 0.1 percent solution of dry skim milk, this solution was used for the investigation. It had approximately the following composition (parts per million): protein, 270; lactose, 530; total organic solids, 880.

The Committee suggested that the investigations be directed towards devising methods for removal of the milk solids by aerobic fermentation. Bacteria, yeast, and molds are being studied for this purpose. Such fermentations by submerged growths usually proceed rapidly. For example, a mold, *Aspergillus niger,* oxidizes a 16-percent glucose solution to gloconic acid in 24 hours *(9)*. A bacterium, *Acetobacter suboxydans,* converts a 20-percent sorbitol solution to sorbose in about 20 hours *(17)*. Torula yeast grown on peanut-waste liquor containing 0.7-percent sugars utilizes the sugars completely in 5 to 6 hours *(7)*. Preliminary studies with dairy waste showed similar trends.

The Chemical Oxygen Demand Method

In the study of many microbial processes, it is essential to follow the changes that various ingredients undergo during fermentation. Laboratory techniques are required that give rapid results. Fortunately, dairy waste is a fairly homogeneous product, and relatively simple procedures have been developed for following changes in oxygen demand of the major constituents during aerobic digestion. Details of these methods are published in the *Sewage and Industrial Wastes Journal (10)*; through the courtesy of Mr. Wisely, the editor, some of the data are presented at this conference.

Although the 5-day BOD test is the accepted procedure for measuring the strength of wastes, its shortcomings are generally acknowledged. It has been stated that such tests are useful only for record and have no value for immediate determination of pollution *(8)*. These shortcomings apply also to its use in a rapid aeration process. Chemical methods for estimating the BOD have been proposed *(6, 13)*, but in these studies a hitherto unpublished dichromate method developed by Eldridge *(4)* and based on Rhame's work was used. When using a fresh synthetic dairy waste, Eldridge obtained a value for the chemical oxygen demand (COD) practically equal to that for the 20-day BOD. The COD and BOD were determined on solutions of skim milk, of lactose, and of casein; Table 1 shows the results. Agreement is close between the COD and the 20-day BOD values but not between the 68-percent COD values and the 5-day BOD. Differences due to the different susceptibilities of the ingredients to microbial attack are apparently

TABLE 1

COMPARISON OF COD AND BOD VALUES OF DILUTE SOLUTIONS OF SKIM MILK, OF LACTOSE, AND OF CASEIN

	COD		BOD	
	Determined ppm	68% ppm	20-day ppm	5-day ppm
Skim Milk	1,052	715	1,056	636
Lactose	516	351	519	431
Casein	604	412	639	327

equalized over longer incubation periods. This chemical oxidation method is reproducible and rapid.

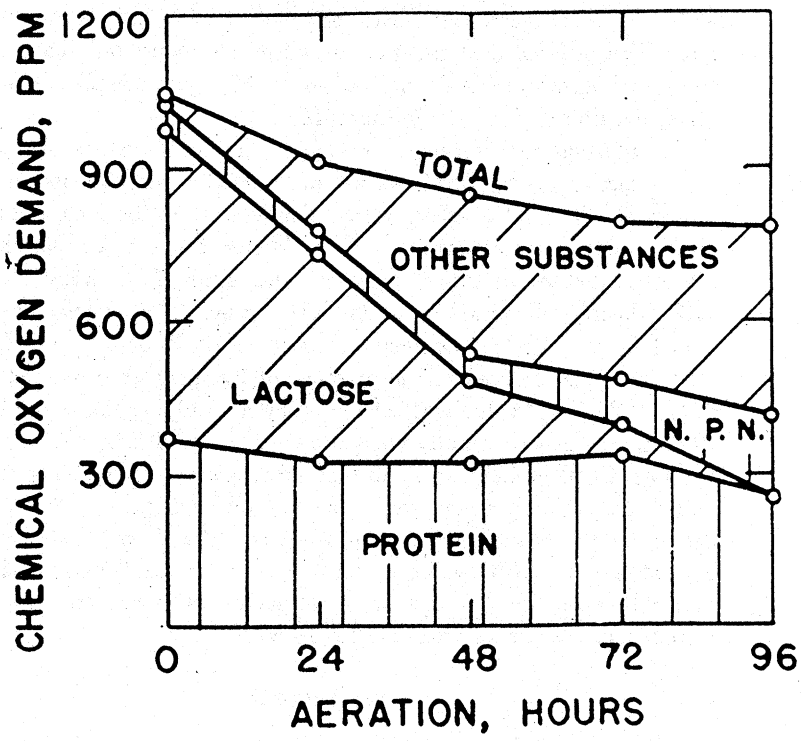
Briefly, the method consists in heating a 5-ml sample with 50 ml of a dichromate oxidizing solution so that the temperature reaches 165-170° C in six minutes. The digested solution is cooled, diluted with 200 ml of water, recooled, and titrated with 0.05 normal thiosulfate. The difference in titration between this value and that obtained on a distilled-water blank, multiplied by 80, gives the COD in milligrams per liter or parts per million *(10)*.

In addition to observing the changes in COD values of the total waste, changes in the COD values of the major constituents were also followed. The COD values were calculated after the lactose and protain contents were determined. The lactose content was obtained by the micro-method of Stiles, Peterson, and Fred *(15)*. Multiplying by 1.12 (theoretical factor) gave its COD value. The protein was determined by the spectrophotometric procedure of Robinson and Hogdan after it was coagulated in the presence of five-percent trichloractic acid *(14)*. The COD value was calculated by multiplying this value by 1.42 (determined experimentally with known amounts of casein).

The COD value for nonprotein nitrogenous compounds was obtained after determining the total organic nitrogen as protein and deducting the coagulated protein from it. The factor 1.42 was used here also. The COD value of the "other substances" was obtained by subtracting the sum of the values of lactose, protein, and nonprotein nitrogenous substances from the total COD value.

from other sources. The equipment consisted of 500 ml gas-washing bottles with fritted-glass discs. Each bottle contained 400 ml of the simulated dairy waste and a small amount of silicone antifoam. After sterilization of the waste, 20 ml of an actively-growing culture was added as inoculum, and sterile air was passed through the solution. At 24-hour intervals, a bottle of solution was removed for analyses.

A yeast, *Saccharomyces fragilis* NRRL-Y-1109, has been selected to demonstrate the proposed methods. Figure 1 presents results obtained with this microorganism. The COD of the protein remained fairly constant throughout the period of aeration. The change in COD of lactose was negligible after 72 hours; whereas that of the "other substances" had markedly increased. The COD of the nonprotein nitrogenous (NPN) fraction had increased but little, but the COD of the total waste had decreased slightly. Mechanical separation of the yeast cells by centrifuging removed practically all the protein and most of the "other substances", and the reduction in COD was from 70 to 75



percent. This indicated that the yeast caused primarily assimilative changes. Tests made with some other organisms gave a sharp decrease in the COD of protein, a marked increase in that of NPN, and increases in the COD values of other soluble substances, indicating primarily hydrolytic action.

These methods make it possible to follow changes in the COD of a dairy waste and its ingredients. As shown schematically in Table 2, analyses are made on the incoming waste, on the whole effluent, and on the effluent after removal of the solids by centrifuging. It is possible to determine the type of action (assimilative, oxidative, or hydrolytic) by relative changes in the COD and by supplementary analyses. Application of these methods is further discussed in the accompanying paper by Hoover and Porges *(5)*.

TABLE 2

SUGGESTED METHOD OF ANALYSIS OF DAIRY WASTE*

	Influent		Effluent		
	COD, ppm	mg/l	Whole COD, ppm	Solubles COD, ppm	Solids mg/l
Total	D		D	D	
Lactose	C		C	C	
Protein	C		C	C	
Nonprotein Nitrogenous Substances	C		C	C	
Other Substances	C		C	C	
Dry Weight		D			D
Nitrogen		D			D
Carbohydrate		D			D
Ash		D			D

Summary

Procedures are described that permit the rapid determination of the total oxygen demand of a dairy waste as well as of its constituents. These procedures make it possible to follow the rapid changes in the oxygen demand of a dairy waste undergoing vigorous aeration. The chemical oxygen demand thus obtained approximates the 20-day BOD value. The application of these procedures to the analysis of dairy waste is discussed.

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